CHAPTER 13

Changing Rules, Changing Games: Evidence from Groundwater Systems in Southern California

Renewable local water supplies are limited in semiarid southern California. Precipitation is unpredictable from season to season, and surface water flow is erratic. Agricultural development on the coastal plain and in the inland valleys exhausted the base flows of the area's main surface streams by the turn of the century. Thereafter, continued agricultural development as well as urbanization of southern California depended heavily on the impoundment and controlled release of storm flows, the importation of water from other watersheds, and the use of groundwater. For most landowners and public or private water suppliers, groundwater use was the easiest and cheapest option, so its use increased rapidly during this century throughout southern California. Eventually in each basin underlying developed areas, annual groundwater use exceeded renewable yields, producing common-pool resource problems.

Groundwater Basins as Common-Pool Resources

A groundwater basin is literally a common pool. Exclusion of multiple pumpers is difficult and costly (unless the basin is so small that an individual can control access to it). Consumption is rival. As water withdrawals from a basin exceed the amount replenished (due to any combination of more pumpers, greater withdrawals by each, or declining replenishment), pumpers visit appropriation externalities upon each other. Underground water levels within the basin decline, lengthening pumping lifts (the distance water must be drawn to the surface). Longer pumping lifts impose increased costs on pumpers. If basin water levels decline far enough, wells go dry and must either be deepened or replaced, at even more cost to pumpers.

In special circumstances, even more dire consequences may result from falling water levels. Depending on the amount of underground water in storage and the composition of soil materials, overlying lands may subside or
even split, damaging overlying structures and endangering residents. In a coastal basin, if groundwater levels drop below sea level, saltwater may intrude into the basin and degrade the quality of the freshwater supply to the point where it is no longer usable for many important purposes, including human consumption.

At the same time that their actions result in these externalities, pumpers can face provision problems of at least two kinds. The first involves the generation of a collective good: increasing water replenishment in order to stabilize the basin. Under normal circumstances, any success at improving replenishment raises basin water levels. As water levels rise, all users benefit from reduced costs of pumping water. The second kind of provision problem involves resisting a collective "bad," such as intrusion of saltwater into a coastal basin. Familiar collective-action problems may be expected to hinder the implementation of a replenishment program or the successful organization of an effort to hold back the sea.

If not overcome, these appropriation externality and provision problems could have produced disastrous consequences for southern California. The region's economic development and population depended crucially on the availability of dependable water supplies. Human health and welfare and tremendous economic assets would be at risk if water became unavailable, or even undependable. At a minimum, destruction of the area's local water supplies would mean total reliance upon imported water supplies that are both more variable and more expensive. Replacing the water supplies, and the storage capabilities, of southern California's groundwater basins could have cost several times more than their preservation (Blomquist 1992) and visited severe economic hardship on the area.

Water users and their representatives tried to alleviate these CPR problems and stave off disaster by changing institutional arrangements. This chapter examines attempts to change rules in three southern California groundwater systems in an effort to illuminate the connections between rules and games in CPRs. These three cases present the least complicated basin governance and management arrangements of eight that have been studied intensively (Blomquist 1992), allowing the analysis here to focus on the levels of action, the resulting operational rule configurations, and their effects on strategies, behavior, and outcomes.

The Levels of Action

Actions by individuals have been defined as occurring at three levels: an operational level, a collective-choice level, and a constitutional level (Kiser and Ostrom 1982). Actions at each level are affected by corresponding sets of rules: operational-level rules, collective-choice-level rules, and constitutional-
level rules. The levels of action, their relation to each other, and their relation to rules, are illustrated in chapter 2.

In the context of a groundwater system, action at the operational level might include water users withdrawing water from wells; action at the collective-choice level might include the adoption or modification of well-spacing regulations; and action at the constitutional level might include the establishment and authorization of the entity making the well-spacing regulations. This example comports with the identification of operational-level action with appropriation, collective-choice-level action with management and policy-making, and constitutional-level action with governance (E. Ostrom 1990).

It is not presumed that the individuals acting at all three levels are the same, nor is it presumed that they are not. It is possible that water users themselves constitute a governing body (e.g., a water users' association) authorized to take collective decisions that apply to all users. It is equally possible that a separate set of officials authorizes the creation of an administrative board and appoints its members, who in turn develop regulations that apply to water users.

The possibility that the same individuals act at all three levels complicates the task of analysis. Among a set of participants within an action arena, "choices of actions within a set of rules as contrasted to choices among future rules are frequently made without recognizing that the level of action has shifted" (E. Ostrom 1991, 2). Nevertheless, to apply the Institutional Analysis and Design (IAD) framework to actual CPR settings, we must maintain analytic separations of participants' actions among the multiple levels.

In the CPR settings represented by the Raymond, Orange County, and Mojave River basins, water users took or initiated actions at multiple levels. Constitutional-level actions established and authorized governance structures; collective-choice-level actions set and modified groundwater management policies and programs (including operating rules for appropriation, provision, monitoring, and enforcement); and the operational-level actions of pumpers, monitors, and the staff and officials of basin governance organizations resulted in actual resource use and the execution of management practices. Actions at all levels in the three cases are described briefly below. For ease of comparison, tables 13.1, 13.2, and 13.3 summarize those constitutional, collective-choice, and operational-level actions.

Raymond Basin

In 1937, action by the city of Pasadena, the largest pumper from Raymond Basin, led to an adjudication of pumping rights among the 30 pumpers throughout the basin. In the shadow of the court, the pumpers negotiated a
TABLE 13.1. Constitutional-Level Actions in the Three Cases

Raymond Basin
- Establishment of stipulated judgment, with continuing jurisdiction retained by the court, establishing the original distribution of pumping rights in the basin, and authorizing the creation of a watermaster service for Raymond Basin with costs paid by pumping rights owners, the creation of a Water Exchange Pool, a system for determining water spreading credits, a system for determining changes in the pumping rights in the Eastern Unit of the basin based on water levels at designated wells
- Modification of judgment, creating the Raymond Basin Management Board (RBMB) as a representative body of pumpers from the basin, with authorization of RBMB to act as watermaster, acquire staff services and basin studies as needed, recommend adjustments in pumping patterns
- Creation of Foothill Municipal Water District (FMWD) to import water for basin communities not already annexed to MWD or under contract with the State Water Project

Orange County
- Creation of the Orange County Water District (OCWD), by act of the state legislature, to be governed by a board of directors elected from divisions by voters residing within the district, with authority to acquire and defend water and water rights on behalf of residents, and to increase water storage and water storage capacity in the basin, but forbidden to participate in an intrabasin determination of pumping rights
- Amendments to the Orange County Water District Act, adopted by the state legislature, authorizing the district board to impose pump taxes, including differential pump taxes (basin equity assessments), to raise revenue for acquisition of supplemental water supplies

Mojave River
- Creation of the Mojave Water Agency (MWA) by act of the state legislature, to be governed by a board of directors representing divisions (and existing municipalities and water districts) within the agency, with authority to acquire and defend water rights on behalf of the residents, to enter into contacts for and raise revenue to acquire supplemental water supplies, and to initiate an intra-agency determination of water rights
- Amendments to the Mojave Water Agency Law, adopted by the state legislature, reorganizing and reducing the size of the agency board of directors

near-unanimous stipulated judgment. Upon its acceptance by the judge in 1945, the judgment became the constitution for Raymond Basin governance (see table 13.1).

The Raymond Basin judgment defined and protected the groundwater rights of the pumpers, limiting their aggregate rights to the determined basin safe yield. It also designated the Southern District office of the California Department of Water Resources (DWR) as watermaster to monitor and report on the administration of the judgment. And it retained for the court continuing jurisdiction to enforce the judgment and to modify its provisions.

In 1984, the judgment was modified to create the Raymond Basin Management Board (RBMB), composed of pumpers’ representatives, and to authorize it to take over from the DWR as watermaster and serve as a basin policy-making body. Other constitutional-level action in Raymond Basin entailed the formation of the Foothill Municipal Water District (FMWD) in 1952 under the terms of the state’s municipal water district enabling legislation.

Within this basin governance structure, several collective-choice actions
TABLE 13.2. Collective-Choice-Level Actions in the Three Cases

Raymond Basin
- Modification of basin safe yield determination, with adjustment of pumping rights
- Choice of watermaster (first, DWR, later RBMB)
- Choice of FMWD to provide staff support to RBMB
- Contracting out of data collection, analysis, and report preparation to DWR
- Decisions by RBMB on voluntary adjustments to pumping patterns in basin
- Authorization of watermaster expenditures and actions, and assignment of charges to
  pumpers to finance those expenditures and actions
- Authorization of spreading credits, and of changes in Eastern Unit pumping amounts
- Operation of Water Exchange Pool
- Establishing requirements for metering and monitoring of wells
- Authorization of basin studies and cooperative agreements

Orange County
- Adoption by OCWD board of basin management policies, including targets for replenish-
  ment water purchases and basin pumping as a percentage of total water production
- Establishing requirements for metering and monitoring of wells
- Acquisition and operation of spreading grounds and basin replenishment program
- Construction and operation of injection barrier projects to halt saltwater intrusion along the
  coast
- Approval of OCWD budget and authorization of OCWD expenditures
- Annual determination of pump tax rates
- Authorization of basin studies and cooperative agreements

Mojave River
- Approval of MWA board of agency expenditures, and payments to DWR under provisions
  of State Water Project contract
- Setting property tax rates to cover agency expenditures
- Authorizing basin studies and cooperative agreements
- Authorizing lawsuit to determine pumping rights
- Authorizing purchases of surplus water from DWR
- Authorizing pipeline projects
- Initiating legal actions against upstream development and diversions
- Adopting land use guidelines as recommendations for communities within MWA

have been taken in Raymond Basin (see table 13.2). The court’s continuing
jurisdiction was used in 1955 to alter the determination of basin safe yield and
adjust pumping rights accordingly, and in 1984 to change the watermaster
designation from the DWR to the RBMB. Policy initiatives and policy
changes have authorized water spreading and storage programs, modified
provisions concerning pumping activities in the basin’s Eastern Unit, and
established contracts for staff support and services between the RBMB and
FMWD and between the RBMB and DWR. Operational-level actions by
pumpers, monitors, and others are summarized in table 13.3. Since the rules
developed in Raymond Basin are similar to those developed in five other
neighboring basins, I do not attempt to describe the rules that evolved in
these other settings (see Blomquist 1992 for a detailed analysis of these
systems).
### TABLE 13.3. Operational-Level Actions in the Three Cases

#### Raymond Basin
- Actions of pumpers: water withdrawals, metering of wells, reporting of production, payment of charges for basin administration, water spreading and storage by some
- Actions of importers: FMWD, Pasadena, and others import water for direct delivery or wholesaling to others
- Actions of DWR staff: monitoring wells, gathering data on water pumping, importing, spreading, storage, and so on within the basin, preparation of reports on basin conditions and operation under the judgment
- Actions of FMWD staff: assistance to RBMB members, distribution of annual basin reports to pumpers and other interested parties, financial accounting
- Actions of RBMB members: attending meetings, reviewing reports, monitoring basin conditions, reporting to court

#### Orange County
- Actions of pumpers: water withdrawals, metering of wells, reporting of production, payment of pump taxes for basin administration, replenishment, and barrier programs
- Actions of importers: Anaheim, Santa Ana, Municipal Water District of Orange County, and others import water for direct delivery or wholesaling to others
- Actions of OCWD staff: operation of the basin replenishment and barrier programs, monitoring wells, gathering data on water pumping, importing, spreading, etc. within the basin, preparation and distribution of reports on basin conditions and operation, assistance to OCWD board members, financial accounting
- Actions of OCWD Board members: attending meetings, reviewing reports, monitoring basin conditions

#### Mojave River
- Actions of pumpers: water withdrawals
- Actions of MWA staff: monitoring and reporting on basin conditions, assistance to MWA board members, financial accounting
- Actions of MWA members: attending meetings, reviewing reports

### Orange County

Constitutional-level actions in the Orange County basin occurred primarily in legislative rather than judicial arenas and resulted in a different governance structure. Orange County water users and their representatives obtained state legislative approval of the Orange County Water District Act in 1933. It authorized the formation and powers of the Orange County Water District (OCWD), governed by a board of directors elected by district residents (see table 13.1). In 1953, a set of amendments developed by a committee of water users was submitted to and approved by the California legislature, substantially reconstituting the OCWD—enlarging its territory to cover parts of the basin not originally included, and adding the power to tax pumping directly to cover the costs of basin replenishment programs. In 1968, the OCWD’s basic charter was amended again, authorizing the district to charge differential pump tax rates in order to more effectively discourage pumping and adjust pumping patterns.
The OCWD’s governing board is the authorized policy-making and management entity in the Orange County basin. Its management and policy-making activities are listed in table 13.2. They include both the provision of a basin replenishment program and a freshwater barrier against saltwater intrusion. Operational-level activities of the board members, staff, pumpers, and others are summarized in table 13.3.

Mojave

In 1959, water users along the Mojave River drafted legislation that was approved by the state legislature, authorizing the formation of the Mojave Water Agency (MWA) and defining and limiting its powers (see table 13.1). The MWA was to be governed by a board of directors chosen by resident voters and by existing local governments.

Unlike the situations in the cases above, significant and continuing groundwater overdraft problems had not developed along the Mojave River by the time of this constitutional-level action. The original intention in constituting the MWA was to create an entity to contract with the state for future deliveries of supplemental water from the soon-to-be-constructed State Water Project. Partly as a result, the MWA covers a territory much larger than the groundwater system along the Mojave River, encompassing several other adjacent basins. Nevertheless, the Mojave Water Agency Law and amendments to it granted the MWA extensive authority to engage in groundwater policy-making and management activities.

By 1964, the MWA board and staff had decided to attempt an adjudication of pumping rights for the groundwater system along the Mojave River. A complaint was filed in 1966, but efforts to achieve a stipulated judgment failed, and the action was dismissed in 1976. Without control of pumping, and without authority to tax pumping, the MWA has been unable to effectively operate any basin replenishment or management programs. Collective-choice actions in the Mojave River area have been essentially limited to those listed in table 13.2. Operational-level actions of pumpers and others in the Mojave River groundwater system are indicated in table 13.3.

Linked Action Arenas

In addition to leaving out details of how the actions in the cases occurred, this abbreviated description of the levels of action also leaves out their many connections to other action arenas to which the actors and their water supply problems are linked. As emphasized in chapter 2, collective action in CPR settings frequently transpires in multiple, linked action arenas, as well as at multiple levels within an action arena.
The governance and management of groundwater systems in southern California were and are closely connected with the development of imported water supplies. Several southern California cities, including some in the Raymond and Orange County basins, were original members of the Metropolitan Water District of Southern California (MWD), which constructed and operates the area’s aqueduct from the Colorado River. Most communities in the Raymond Basin have annexed to MWD, and all member agencies have representation on MWD’s Board of Directors. Later, MWD contracted with the California Department of Water Resources for northern California water via the State Water Project, as did the Mojave Water Agency. MWD is now the largest supplier of water to southern California communities, including water for groundwater basin replenishment. Decisions and actions taken concerning the Colorado River Aqueduct and the State Water Project bear importantly upon the use and conditions of the groundwater basins.

Closer to home, the Raymond and Orange County basins are embedded within river systems that have governance arrangements to represent the interests of upstream and downstream areas. Water users in Raymond Basin are indirectly represented on the San Gabriel River Watermaster, and those in Orange County are indirectly represented on the Santa Ana River Watermaster and the Santa Ana Watershed Project Authority.

Actors and actions in the three cases also are linked with the actions of flood control agencies in Los Angeles, Orange, and San Bernardino counties. Those agencies operate flood-control impoundments, from which accumulated storm flows can be released into spreading grounds for groundwater replenishment. The U.S. Army Corps of Engineers operates Prado Dam and Flood Control Reservoir, which controls flows into the Orange County basin, and the Forksite Dam below the headwaters of the Mojave River.

Issues of wastewater collection, reclamation, and reuse—including use for basin replenishment—link basin governance and management systems to county sanitation districts, municipal and regional wastewater treatment facilities, and the California Department of Health Services. Water quality concerns involve the Department of Health Services, Regional Water Quality Control Boards, the U.S. Environmental Protection Agency’s Superfund program, and so on. Responses to water quality problems can affect pumping patterns and replenishment options.

**Operational-Level Rule Configurations**

Operational-level actions in CPR settings are defined by operational-level rules. Operational-level rules require, authorize, or forbid certain actions, affecting the incentives and choices of operational-level actors. Their
operational-level actions interact with physical attributes of the CPR to yield outcomes ranging from sustained development and more efficient use to resource exhaustion and destruction. Therefore, to examine the effects of the collective actions described above on CPR conditions in the three cases, we first examine operational-level rules and their effects on operational-level actions.

Following the IAD framework, rules are assigned to seven categories: position, boundary, scope, authority, information, aggregation, and payoff (see chapter 2). Where working rules governing particular actions have not been established or modified, the rules in that category are presumed to remain at default settings; in the analysis below, operational-level scope and aggregation rules are left at default settings.

Table 13.4 presents a side-by-side comparison of some operational-level rules in the three cases. The figure does not include every operational-level rule in use; it emphasizes operational-level rules that were explicitly adopted or modified in at least one of the three cases. For simplicity of presentation, the presence or absence of a particular rule in each case is indicated by a yes (Y) or no (N) answer to a question, although this limits the presentation of details and qualifications of particular rules.

Even with these limitations, table 13.4 illustrates several features of the operational-level rules that resulted from the constitutional-level and collective-choice-level actions of participants in the three cases. First and most obviously, the operational-level rules in use differ noticeably across the cases; pumpers and monitors in the three basins do not operate under identical institutional arrangements. Second, the Mojave River case stands out from the others; virtually no rules regulating pumpers’ activities have been adopted there (the rule requiring large pumpers to report extractions is a state law applying to several southern California counties). The operational-level rules in the Mojave River case are essentially the same as those prior to the collective actions taken in the other cases, and therefore provide a useful comparison.

Third, the operational-level rules for the Raymond and Orange County cases reveal different approaches to basin management. In Orange County, pumpers’ rights to water withdrawals are not defined or transferable or restricted to specific quantities; in the Raymond Basin, they are. In Raymond Basin, new pumpers are barred from use of the basin unless they acquire rights from existing pumpers. In Orange County, overlying landowners who are not currently withdrawing water for use on their lands cannot be barred from doing so in the future. Orange County has imposed a pump tax to support a basin replenishment program; in the Raymond Basin, individual parties with access to supplemental water may spread and store it under-
### TABLE 13.4. Partial Configurations of Operational-Level Rules in the Three Cases, 1990

<table>
<thead>
<tr>
<th>Rule Type and Rule</th>
<th>Raymond</th>
<th>Orange</th>
<th>Mojave</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Position Rules</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Does position of authorized pumper exist?</td>
<td>Y</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Does position of monitor exist?</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td><strong>Boundary Rules</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Can any overlying landowner pump from the basin?</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Are new pumbers required to obtain rights from existing pumbers?</td>
<td>Y</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td><strong>Authority Rules</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Are pumbers restricted in amount pumped?</td>
<td>Y</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Are all pumbers required to install meters?</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>Can monitors enter onto pumbers' property to check wells and meters?</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>Are pumbers authorized to elect representatives?</td>
<td>Y</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Can pumbers acquire rights from each other (apart from transferring land)?</td>
<td>Y</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Can pumbers store water in basin for later recapture?</td>
<td>Y</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td><strong>Information Rules</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Are large (&gt; 25 after/year) pumbers required to report pumping?</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Are small pumbers required to report pumping?</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>Are pumbers entitled to receive regular reports on basin conditions?</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>Are monitors required to report their activities and findings to pumbers?</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>Do reports list each pumper's water production?</td>
<td>Y</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td><strong>Payoff Rules</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Is pumping taxed to pay for administrative costs of basin management?</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>Is pumping taxed to pay for basin replenishment?</td>
<td>N</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>Can fines or penalties be assessed for over-pumping?</td>
<td>Y</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Can pumbers be offered incentives to adjust pumping patterns?</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
</tr>
</tbody>
</table>
ground, but there is no basinwide replenishment program. And, in the Raymond Basin, each pumper’s annual water withdrawals are published in a report distributed to all pumpers.

That information rule—that every pumper is entitled to see every other pumper’s production data—underscores a point made in chapter 2 about the configurational nature of rules. At any level of action and in any action situation, rules operate configurally, meaning that the effect of a change in one rule depends on the other rules in use (E. Ostrom 1991, 7). By itself, the effect of the authority-rule change in the Raymond Basin restricting each appropriator to a specific quantity of water per year would be relatively unclear. When that rule change is taken together with other rules in use, a clearer picture emerges. If pumpers are restricted to a specific quantity of withdrawals and are required to install and maintain meters on their wells and monitors are employed to check on pumpers’ wells and meters and monitors report each pumper’s withdrawals to all other pumpers and fines can be imposed on pumpers who exceed their allotted withdrawals or fail to install or maintain accurate meters, then the effect of the pumping restrictions can be anticipated with greater confidence. With such a configuration of rules, one would anticipate that pumping restrictions would likely result in restraint by pumpers.

Operational-Level Rules and Game Structure

We may now address directly the relation of operational-level rule configurations to the structure of games, examining in our groundwater context the claim in chapter 1 that “rules can change the games that appropriators play.” As stated in chapter 4, many analysts have argued that the incentives and choices for appropriators in CPR settings where there are no restrictions on access and use are very similar to those facing players in a Prisoner’s Dilemma (PD) game. Each appropriator’s dominant strategy is to exploit the resource without constraint, or to decline to contribute to its preservation and maintenance, regardless of what other appropriators do. Figure 13.1a depicts this situation.

Among the southern California cases, the operational-level rule configuration for the Mojave River case is characterized by very few rules restraining access and use, and virtually no regular arrangements for monitoring use. Given the value of water supplies in a rapidly developing desert region like the Mojave River area, we would anticipate ceteris paribus that pumpers would respond to the lack of enforceable restraints on access and use by taking actions that are individually rational, placing ever-increasing demands upon the resource. Doing so, they collectively realize a deficient equilibrium. This has been the case in the Mojave River area, and in the other groundwater systems of southern California prior to collective actions (E. Ostrom 1990, 108).
Fig. 13.1. Prisoner’s Dilemma, the assurance problem, and the rule-ordered pumping game

The Mojave River case adds another empirical example to the often-noted connection between a relatively open-access CPR and a PD game. But developing the connection between operational-level rules and game structures entails moving beyond this CPR-PD equation and examining how changes in operational-level rules can change game structures. "The task of crafting institutions is to change the incentives so that free riding is no longer the dominant strategy" (E. Ostrom 1992, 64n).

One alternative conception of the game structure of a CPR has been offered by Runge (1984a, 1992). He has stated that most actual CPR situations more closely resemble the Assurance Problem (AP) than the PD, because of the potential joint benefits as well as the joint harms facing users of a valued common resource. In the AP (fig. 13.1b), there are two equilibria and no dominant strategies. Individuals’ strategy choices depend on their expectations of others’ strategy choices. In this structure, Runge 1984a identifies strong incentives for developing institutional arrangements that will coordinate appropriators’ expectations about each other’s behavior.
Quick examination of the payoff structures reveals a key difference between the AP and the PD. The AP reduces the PD’s temptation to “defect” (strategy 2) when the other player “cooperates” (strategy 1). In the AP, the preferred choice of strategy if the other player cooperates (strategy 1) is to cooperate (strategy 1). The possibility of defecting when others cooperate is not blocked (the strategy 2–strategy 1 combination still exists), but the payoff from this combination is less than the payoff from the strategy 1–strategy 1 combination.

The different characterizations of CPR problems as resembling PD or AP game structures is useful to a point, but our interest is in the effects of rule changes on incentives and behavior. As a first step in this inquiry, then, we are not as interested in whether a PD or AP characterization of a CPR problem is the correct one, but in how a change from a PD structure to an AP structure could be brought about.

Like Runge (1984a, 161), we do not wish to ascribe altruistic behavior to appropriators of a common resource. Altruism solves too much, since altruistic individuals would cooperate even if others defected. Rather, we are interested in the change of incentives that could encourage rational and self-interested appropriators to cooperate when others do the same.

A rule change that established sufficient sanctions for noncooperative behavior, coupled with institutional arrangements authorizing monitoring activities, could lower the payoff from noncooperative behavior. It might even be lowered to just below the benefits from cooperating when others cooperate. Thus, it is at least feasible that changes in operational-level rules can alter the payoff structure of a PD game in the direction of an AP game. (Note: the defecting option is not blocked, but the choice of this option results in a smaller payoff than before.)

Is there any empirical support for this proposition? Returning to the configuration of operational-level rules in use in the Raymond and Orange County cases, we find pumpers subject to sanctions if they engage in noncooperative behavior such as overpumping, failing to report production, and failing to pay assessments based on their pumping rights or their actual withdrawals. Those sanctions include fines and (in the Raymond case) potential loss of rights to use. Furthermore, pumpers are required to meter and report their production, and monitors can check meters and wells. Under these circumstances, one would anticipate that a typical pumper in a given time period would find the payoff from attempting to free ride sinking below the payoff from cooperating as long as others do.

In the AP, although the temptation to defect while others cooperate is curtailed, the risk of being a “sucker” remains. The payoff from cooperating while others defect remains lower than the payoff from defecting while others defect. Suppose that monitoring and enforcement could reduce the chances of
being a "sucker" and raise the chances of being caught and sanctioned for defecting. Suppose further that the payoff for cooperating now exceeds the payoff from defecting. Appropriators' best response would then be to cooperate even if others defect. The AP could be transformed into something like the "rule-ordered pumping game" shown in figure 13.1c.

This transformation is more difficult to imagine, but Runge 1984a, 1992, and Wade 1987 supply some rationale for its feasibility. Runge (1992, 27) raises the possibility that appropriators of a common resource might take into account more than the individual benefits and costs they receive from following or breaking the rules that coordinate resource use. If they include the opportunity costs of foregone joint benefits and the expected costs of developing new rules if defecting behavior leads to the breakdown of existing arrangements, appropriators may recognize incentives to maintain those arrangements by adopting a cooperative strategy over numerous iterations.

The key institutional arrangements to be supplied and maintained, then, provide information to appropriators about each other's actions and the level of compliance with the rules. This includes the knowledge that one's own actions are known to others: "The more information player 1 has about player 2 and others' ability to predict his actions, and vice versa, the more mutual confidence or assurance exists" (Runge 1984a, 164). In an irrigation context, Wade (1987) refers to the degree of "transparency" of CPR arrangements, and articulates somewhat more specifically how such operational-level institutional arrangements might work:

in many situations individual irrigators will restrain their water rule breaking if they are confident that others will also refrain and if they are confident that they will still get as much water as they are entitled to (even if not as much as they would like). They will more likely refrain from cheating if they are confident that by doing so they will not be the "suckers." Where people are motivated by an "I'll restrain if you restrain" calculation, then an institution (such as an irrigation department) that convinces them that these expectations are justified can promote voluntary compliance with the rules. (Wade 1987, 178)

Empirical evidence from the Raymond Basin case illuminates Runge's reasoning about the incentives to cooperate when information is available to all participants. The empirical evidence also supports Wade's reasoning about the role of institutional arrangements in promoting voluntary compliance with rules by raising participants' confidence in each other's rule-following behavior. Raymond Basin pumpers not only institutionalized rules restricting quantities of water withdrawn, requiring well meters to determine quantities withdrawn, mandating contributions to basin administration on the basis of
quantities withdrawn, and authorizing monitors to check on wells and meters, but also entitling each pumper to an annual report on basin conditions and the water withdrawals of every other pumper. Pumpers receiving such reports become the monitors of each other's behavior and know that their own behavior is equally visible to others. Under those circumstances, the possibility of being played for a "sucker" (at least more than once) by other pumpers is reduced, confidence that noncomplying behavior by any pumper will be caught and sanctioned is raised, and if available sanctions are nontrivial, the payoff for cooperating exceeds the payoff from defecting.

In this rule-ordered pumping game, it makes sense to follow rules and contribute to provision even if someone else defects or free rides. Runge adds, however, that widespread noncompliance by others could still lead an individual appropriator to drop his or her cooperative strategy: "where noncompliance is the rule, it does not seem fair to many that they pay as part of a minority" (1984a, 161). This is an important point, if it is meant to suggest that institutional arrangements can erode over time if not maintained. However, it remains unclear how widespread noncompliance emerges in any given time period if each individual faces greater incentives to cooperate and contribute than to defect and free ride.

**Rules, Actions, and Outcomes: Evidence from the Cases**

In the Raymond and Orange County cases, the relatively transparent institutional arrangements developed by pumpers and others over time have produced something like a rule-ordered pumping game, where pumpers respond to the incentives and choices available by selecting a strategy of cooperation. Although the institutional arrangements have been in effect in Raymond Basin for nearly 50 years and in Orange County for 40 years, sanctions have never been applied for noncompliance. When instances of noncompliance with rules requiring meter installations, meter repairs, payment of contributions, or restrictions on water withdrawals have occurred, reporting of the violation has sufficed to bring about compliance in the next time period without the application of sanctions. Although the rule-ordered pumping game with its dominant strategy of cooperation seems unlikely in the context of the literature on CPRs, the operational-level rule configurations put in place in the Raymond and Orange County cases appear to have created something approaching it.

Our final inquiry is whether and how the operational-level rule configurations in these cases appear to be linked to outcomes, that is, changed CPR conditions. Table 13.5 briefly summarizes the status of basin conditions in the three cases as of 1990; greater detail on institutional performance is available in Blomquist (1992). The first two questions in table 13.5 address whether the
TABLE 13.5. Comparison of Basin Conditions in the Three Cases

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Raymond</th>
<th>Orange</th>
<th>Mojave</th>
</tr>
</thead>
<tbody>
<tr>
<td>Has imported water use increased relative to basin water use?</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Is basin water relied on to a greater extent for emergency and “peak” supplies?</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Is the basin in continuing overdraft condition?</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Are basin water levels rising, stable, or falling?</td>
<td>Stable</td>
<td>Stable</td>
<td>Falling</td>
</tr>
<tr>
<td>Are water consumers charged roughly the replacement cost of water supplies?</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Is total water use in the basin rising, stable, or falling?</td>
<td>Stable</td>
<td>Stable</td>
<td>Rising</td>
</tr>
<tr>
<td>Is per capita water use in the basin above or below the state average?</td>
<td>Below</td>
<td>Below</td>
<td>Above</td>
</tr>
<tr>
<td>Is per capita water use in the basin rising, stable, or falling?</td>
<td>Falling</td>
<td>Falling</td>
<td>Stable</td>
</tr>
</tbody>
</table>

groundwater system is now used more efficiently, as part of a conjunctive-use system in which imported water is used for average daily requirements and the groundwater storage capacity is relied upon primarily for peaking and emergency supplies. The next two questions address overt measures of groundwater conditions—the presence of persistent overdraft and the status of underground water levels. The remaining questions address whether the institutional arrangements governing water use have encouraged rational water pricing that provides water consumers with incentives to conserve water in this relatively dry region, and whether water consumers have responded to those incentives.

As mentioned above, the operational-level rules governing access to and use of the Mojave River groundwater system have remained very near the structure of a PD game. Accordingly, in light of previous theory and research on CPRs under such circumstances, we would expect basin conditions to be deteriorating. Table 13.5 illustrates that in the Mojave case, basin overdraft continues, water levels are falling, total water use is rising, and per capita water use is above the state average and holding steady despite substantial statewide efforts to encourage water conservation.

Table 13.5 shows a clear contrast between the Mojave case and the Raymond and Orange County cases on these outcome criteria. The groundwater systems in those cases are relied upon to a greater extent for storage and peak use while imported water is used to greater degree for direct use. Overdraft has not continued, and underground water levels have stabilized. Moreover, in Orange County, an extensive program of artificial basin replenishment has operated for nearly 30 years and freshwater barriers against saltwater intrusion have functioned successfully for 20 years. In both basins, water
consumers are charged prices for water that approximate its replacement cost (i.e., the marginal cost of additional imported water), and their total and per capita water consumption has responded by falling below the state average and declining.

As discussed in chapter 4: "When rules . . . are changed, the resulting games may produce incentives leading to the same, improved, or worse outcomes for the participants." The comparison of the cases in table 13.5 offers evidence of rule changes in two cases leading to a changed game that yields improved outcomes for the participants, and of a failure to make rule changes in the remaining case leading to a perpetuation of a game that yield deteriorating outcomes for the participants. In the Raymond and Orange County cases, the institutional changes correspond with Elinor Ostrom's general characterization that "in all cases in which individuals have organized themselves to solve CPR problems, rules have been established by the appropriators that have severely constrained the authorized actions available to them" (1990, 43). Even so, judging from the extent of rule compliance by pumpers in those two cases, the institutional changes also appear to represent or approximate rule reforms, defined in chapter 4 as rule changes yielding outcomes preferred by all players. Based on the outcomes summarized in table 13.5, they also meet the definition of a welfare improvement, where the aggregate payoff of a rule configuration is greater than that of its predecessor.

Conclusions

As stated in chapter 2, "The substantive questions of this book relate to how and when individuals using [CPRs] establish enforceable rules that enable them to use these resources relatively efficiently. The theoretical questions of this book relate to how rules are linked to strategic behavior within well-structured, repetitive situations that can be analyzed as games." Empirical evidence from groundwater systems in southern California bears upon both sets of questions and relates directly to the following propositions advanced in chapters 1 and 2.

1. Rules shape action situations, including situations that can be represented as games (chap. 1).
2. Rules shape action situations by affecting the incentives and choices available to individual actors, to which rational actors respond by adopting certain strategies and behaviors, which affect outcomes (chap. 2).
3. Changing rules can therefore change action situations in ways that motivate individuals to adopt different strategies and behavior, potentially yielding different outcomes (chap. 1).
4. Rule changes can be developed and deliberately chosen by the actors in an action situation, as well as imposed from outside (chap. 2).

5. Actors in an action situation change the rules shaping that situation by taking actions at multiple levels (chap. 2).

6. Actions frequently occur not only at multiple levels within a particular action arena but also in linked action arenas (chap. 2).

In these groundwater systems, water users took or initiated constitutional-level actions to create and modify collective-choice institutions and authorized actors in positions in those institutions to establish and enforce groundwater management policies and programs. In two of the three cases, those collective-choice institutions were employed effectively to establish or change rules guiding operational-level activities of pumpers, persons engaged in resource provision and maintenance, and persons engaged in monitoring and enforcement. This evidence supports three of the above propositions, namely that rule changes can be developed and deliberately chosen by the actors in an action situation, through actions taken at multiple levels and in linked arenas.

In two of the cases, the operational-level rule configurations resulting from processes of institutional change appear to be associated with changes in pumpers’ strategies and behaviors, and with improved use of common resources. Elinor Ostrom’s characterization of the West and Central basins applies equally well to the Raymond and Orange County cases: “After several decades of institutional change, the resulting institutional infrastructure . . . represented a major investment that dramatically changed the incentives and behaviors of participants and the resulting outcomes” (1990, 141). In the Mojave case, failure to change substantially the operational-level rule configuration appears to be associated with the perpetuation of pumpers’ strategies and behaviors, and with continued deterioration of the condition of the common resource. This evidence supports the other three propositions, namely that rules shape action situations by affecting actors’ incentives and choices and thus their adopted strategies and behaviors, and that rule changes can therefore result in actors’ adoptions of different strategies and behaviors, yielding different outcomes.

Empirical evidence from the southern California experience cannot be read as prescribing a formula for the sustainable development and efficient use of all CPRs. Even in the relatively successful Raymond and Orange County cases, the constitutional and collective-choice actions produced operational-level rule configurations that differed substantially. The evidence from the southern California experience does, however, reinforce the close relationship between rules and games.